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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a requ st f r filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53 (c).

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☒ *Additional inventors are being named on the 1 separately numbered sheets attached hereto*

TITLE OF THE INVENTION (280 characters max)

PHILIPS RESEARCH MAC PROPOSAL FOR UWB: DRP - DISTRIBUTED RESERVATION PROTOCOL

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ENCLOSED APPLICATION PARTS *(check all that apply)*

☒ Specification *Number of Pages* ☐ CD(s), Number

☐ Drawing(s) *Number of Sheets* ☒ Other (specify) Disclosure 299284 - 9 pages

☐ Application Data Sheet. See 37 CFR 1.76

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT *(check one)*

☐ Applicant claims small entity status. See 37 CFR 1.27.

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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☒ No.

☐ Yes, the name of the U.S. Government agency and the Government contract number are: _____.

Respectfully submitted,
SIGNATURE [signature]

Date FEBRUARY 6, 2004

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Docket Number: US040121

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PROVISIONAL APPLICATION COVER SHEET
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Philips Research MAC Proposal for UWB: DRP - Distributed Reservation Protocol

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2.99284

Revision History

REV	DATE	BY	Status	Remark
0.1	04/02/03	J. Habetha	Draft	Initial version without figures
0.2	04/02/03	J. Habetha	Draft	Typo corrections, Priority handling in section 2.5 added, References added
0.3	04/02/04	G. Hiertz, J. Habetha	Draft	Changed units for reservation parameters, new figure on calculation of reservation time, added some explanatory text in several sections.
0.4	04/02/05	J. Habetha	Draft	Added Reservation-Request, Reservation-Response, a lot of figures, new text for protocol operation, additional claims, etc.

Abstract

1. Introduction

The proposed new MAC is distributed, i.e. all devices have the same protocol behavior and hardware/software capabilities. This makes the protocol very well suited for ad hoc applications and peer to peer networking. Furthermore, the proposed MAC is based on medium reservations of the devices, which eliminates sensing and collision times on the medium. Owing to the medium reservations, a very efficient real-time, rsp. streaming support is guaranteed, the data throughput is increased and the mesh networking support significantly improved. Another important characteristic of the protocol is that reservations are issued by the receiver of a packet or burst of packets. This avoids the hidden-terminal problem, which is otherwise hampering an efficient operation in mesh networking scenarios. Finally, a sophisticated beaconing concept allows for very efficient power save modes without interrupting large packet bursts. The beaconing can further be used for the mutual device discovery in the ad hoc network.

2. Protocol Description

2.1. Overall superframe layout

The time is divided into superframes, as shown in Figure 1. At the beginning of each superframe there is a beacon period followed by a data transmission phase.
The beacons within the beacon phase are separated by a "Short Beacon Inter-frame Space" (SBIS). The beacon interval is separated from the data transmission phase by a "End Beacon Interval Space" (EBIS).

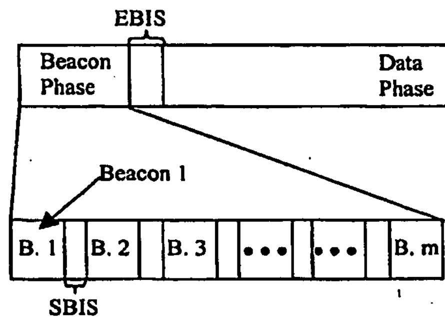

Figure 1: Overall superframe layout

2.2.MAC Protocol Operation

Before the two phases "beacon phase" and "data phase" are described in more detail, an overview of the Medium Access Control (MAC) protocol operation is given in this section.

Devices, which are planning a data transmission, propose a starting point in time, duration, priority, etc. of the transmission to the intended receiver(s) of the planned transmission. A dedicated "Reservation-Request" management frame is used for this purpose. The receiver evaluates whether the medium is free on his side during the planned transmission time in the future. In order to be able to carry out this evaluation, every device shall locally store the reservations of all other devices. If the receiver has no other reservation stored for the intended period, it gives a positive response to the sender of the Reservation-Request. A dedicated "Reservation-Response" management frame is used for that purpose. In case that the receiver is not willing to accept the transmission or in case that it has stored another reservation during the planned time, the receiver sends a negative Reservation-Response to the sender. In this negative Reservation-Response the receiver can optionally propose an alternative time for the planned transmission.
If sender and receiver have successfully negotiated a reservation, both devices include the reservation information in their respective beacon-frames in the subsequent MAC-superframe. The beacons are transmitted in the beacon-phase at the beginning of a superframe. The reason to include the reservation information in the beacon is to inform all devices surrounding the sender and the receiver, about the forthcoming transmission. Devices, which receive such reservation information in the beacon of another device, shall store this reservation information locally and shall defer from

any medium access at the announced point in time on the respective channel hopping sequence and for the duration of the planned transmission. In other words, the locally stored reservation information is used to determine free time on the wireless medium for own transmissions, in which the device is either sender or receiver of the transmission. For their own transmissions the devices shall select periods, in which no reservations of other devices are registered. The process of Reservation-Request, Reservation-Response, announcement in the beacon frames of the involved devices and subsequent data transmission is illustrated in Figure 1.

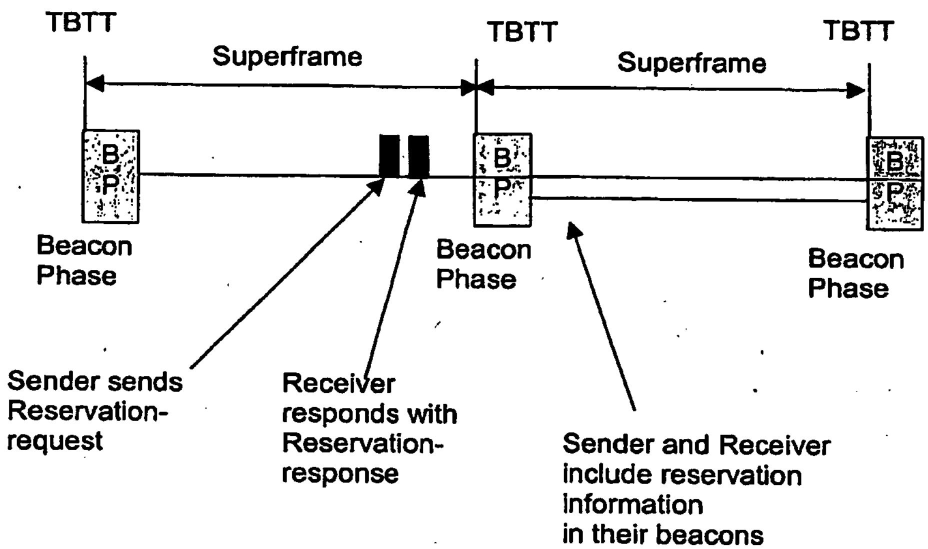

Figure 1: Overview of MAC protocol operation

The protocol allows for a dynamic reservation of transmissions in every superframe. However, in order to save the overhead of the Reservation-Request and Reservation-Response message exchange, a reservation shall be automatically interpreted as reservation not only for the subsequent superframe but also for all following superframes. In case that the sender wants to change the reservation it shall distribute a new reservation information inside its beacon. If the sender has ended the connection, it shall include a reservation information in its beacon with the same starting time as the corresponding previous reservation but with zero duration. Upon reception of a reservation information with zero duration, the devices shall locally delete the corresponding reservation information.

In case that a device receives a reservation information for a time in the future, for which the device wanted to reserve the medium itself, the device is only allowed to distribute this own reservation, if the priority of the planned transmission is higher than the priority of the received reservation. In case of equal priorities the medium is reserved in a first come, first served order. If a device detects that its own reservation is overruled by another device, it shall cancel its planned transmission and try to make a new reservation in a subsequent superframe. All devices should modify their locally

stored reservation information, in case that they receive a reservation with a higher priority for the same or an overlapping time-period.

Summarizing the following rules shall be applied when a station tries to reserve the medium. If the medium is already reserved to a station, another station may override this reservation only when its reservation is of higher priority. The station whose reservation is overridden will delay its reservation since it overhears another reservation of higher priority. If the channel is already reserved by a reservation of the same priority the reservation which is existing on a longer term may not be delayed by other reservations.

2.3. Beacon phase

During the beacon period all devices that are either in active state or in standard power-save mode shall transmit their own beacon. The frame body of a beacon shall contain at least the following fields and information elements (IE), as illustrated in Figure 2:

- Beacon number field
- Device Identifier (MAC-address) field
- Sleep period field
- Device capability information element
- Beacon position occupancy information element
- Zero, one or several "Reservation information elements"

	Beacon number	DEV ID	Sleep period	DEV cap	Beacon Pos. Occup. IE	Reserv. IE
Bits:	8	48	8	TBD	n*x	m*y

Figure 2: Structure of a device beacon

The beacon number shall represent the order of the beacons, i.e. the first beacon shall have the number 1, the second beacon in the superframe the number 2, etc. With a beacon number field size of 8 bit, 256 devices can be supported simultaneously.
The device ID is the 48 bit MAC address of the device. The DEV-cap information element contains information regarding the capabilities of the device. The sleep period field gives the period in number of superframes, during which the device will be in deep sleep-mode, which will be described in more detail in section 2.5.
The "beacon position occupancy" information element contains a list of received beacons of other devices. Each element in the beacon position occupancy field shall contain the number of the beacon (position), a short device ID of the device, which has sent the beacon, as well as the duration of the beacon in symbols (multiples of 312.5 ns) (see Figure 3). The beacon position occupancy field is required in each beacon, because other devices have to be informed, whether their beacon has been successfully received or whether a beacon collision has occurred. The latter can be due to the fact that two devices have randomly chosen the same beacon position or due to a hidden terminal problem in mesh network scenarios. In the latter scenario a device might receive two beacons from different devices at the same position in the

beacon phase, if these two other devices could not hear each other and are not aware of the other device's beacon position.
The duration of the beacon has to be given in order to inform devices, which are not able to receive this beacon, when the beacon will end.

Element ID	Length	Info 1	•••	•••	Info n

	Beacon number	Short DEV ID	Beacon duration
Bits:	6	TBD	10

Figure 3: Structure of the "Beacon Position Occupancy" information element

The reservation information element shall only be included, if the device is either sender or receiver of a future transmission in this superframe. The reservation information element contains the following parameter, as shown in Figure 4:

- The element ID (of a reservation element)
- The length of the IE
- A "Tx/Rx bit", which indicates whether the device is sender or receiver
- The ID of the communication partner (or multicast group) of the planned transmission
- The Target Beacon Transmission Time (TBTT) offset, which indicates the starting point of the reserved transmission in the current superframe, measured as offset from the TBTT of this device.
- The duration of the reservation
- The priority of the planned transmission
- The channel hopping sequence of the planned transmission

	Element ID	Length	TX/RX	Dest/ Source ID	TBTT Offset	Duration	Priority	Hopping sequence
Bits:	8	8	1	TBD	19	19	3	6

Figure 4: Structure of the Reservation Information Element

The "Tx/Rx bit" shall be set to "0", if the device is sender of the planned transmission and set to "1", if the device is a receiver of the planned transmission. The ID of the communication partner shall be the ID of the receiver or multicast-group in case that the device is the sender of the transmission and shall be the ID of the sender in case that the device is a receiver of the planned transmission.
The starting point of the planned transmission is given relative to the beginning of the respective beacon in multiples of symbols (312.5 ns). The duration of the planned transmission is also given in multiples of symbols (312.5 ns). The priority of the

transmission can have a value between 0 and 7, where the priority is chosen according to IEEE 802.1d Annex H.2.
The channel hopping sequence of the planned transmission is given in order to allow for parallel transmissions of other devices in case that the resulting Signal-to-Noise ratio would be sufficient.

As mentioned before, the beacons within the beacon phase are separated by a "Short Beacon Inter-frame Space" (SBIS).the beacon interval is separated from the data transmission phase by a "End Beacon Interval Space" (EBIS).
The length of the beacon phase can be variable, as devices might join or leave the network. A variable beacon phase has the big advantage that the overhead of the beaconing gets minimal in typical cases of one sending and one or a few receiving devices.
If a new device joins the network it shall listen to at least one full first beacon interval and evaluate the information inside the beacons. From the received beacons as well as the "beacon position occupancy" fields, the new device shall deduce occupied beacon positions. In the same or the following superframe (depending on the processing speed of the device), the device shall transmit its beacon SBIS time after the (last) beacon with the highest beacon number in the first beacon phase. If two devices have chosen the same additional beacon position/number, e.g. that they have joined the network in the same superframe, the devices will detect the collision in the following superframe by the missing "beacon position occupancy" information. In such a case a device shall re-transmit its beacon in the superframe, which followed the last try, at the same position with a probability of 1/n+1, where n is the number of the current trial.
A back-off of the additional beacon transmission is not possible because the other devices would interpret the pause time after the last beacon as the end of the beacon phase.
If a device has left the network, its old beacon position will be empty. In such a case, all the devices with higher beacon numbers, which detect the missing beacon, shall decrease their beacon number by 1 and shift the sending of their beacon accordingly in the beacon that follows the change.
Empty beacon positions will not be "re-filled" by new devices that join the network, because no new device might join after another one has left. Waiting for a new device to join and re-fill the empty position would waste precious frequency resources.

2.4. Data transmission phase

A data transmission is always initiated by the receiver of the transmission by sending a Poll-frame to the sender. This has the advantage that the sender will only start its transmission, if it is ensured that the medium around the receiver is clear.

The receiver shall perform a back-off before sending the Poll-frame, which shall start at the given start-time of the transmission or after the end of any ongoing transmission, whatever ends later. Even though the reservation mechanism should exclude any collisions, it might still be possible that a device has not received the reservation information, in which case the back-off can eliminate a potential collision. However, as the reservation mechanism makes a collision very improbable, the back-off can be very short.

A "Short Data Infer-frame Space "(SDIS) time, after the reception of the Poll-frame, the sender shall start the transmission of the data frame.
The sender can also send a burst of data packets, in which packets are separated by SDIS pause times. As the SDIS may be very short, it might be possible to waive the usage of OFDM preambles - which are needed to synchronize the receiver – since the receiver may be still synchronized to the transmitter.
The receiver acknowledges a single or a burst of packets by an ACK frame.
The ACK-frame contains information, which acknowledges each preceding data packet, thus allowing a selective reject of failed frames.

The sender shall ensure that the time required for the back-off of the receiver, the Poll-frame, SDIFS, the burst of packets and the ACK does not exceed the length of the reservation. In case that a transmission of another device had blocked a certain interval during the reserved interval, the sender shall reduce the amount of data sent accordingly in order to guarantee the ending of the transmissions on schedule.

2.5. Power Management

All devices in the so-called "Standard Power-save Mode" shall be awake during the beacon phase, shall send a beacon and can go into sleep for the rest of the superframe, in case that they are not mentioned as receivers of planned transmissions of other devices.
Devices in "Active Mode" can fall asleep after their own transmission/reception until the beginning of the next beacon phase.
Devices can also enter a "Deep Power-save Mode". In this power-save mode devices can fall asleep for more than one superframe in a row without waking up for the intermediate beacon phases. For this purpose a device shall signal in its beacon the number of superframes, in which the device will not listen to the beacon phase and not send an own beacon. The devices, which received the beacon of the device in deep power-save, shall store this information and shall not attempt any data transmissions directed to the sleeping device during its sleep phase. Furthermore, the other devices shall include the beacon of the sleeping device in the "beacon position occupancy field" in their own beacon, even though no beacon from the sleeping device was received. The reason is that new or moving devices should not occupy the beacon position of the sleeping device.
A device in Deep-Power Save shall not announce any planned reservations in the beacon after the deep sleep phase and shall not attempt any transmissions in this superframe. This is required in order to ensure that a device in deep power-save will first update its knowledge about existing reservations before making any own reservations.

References

G. Hiertz, R. Bagul, O. Wischhusen, J. Habetha, P. May: A method of decentralized medium access control in a communications network, Patent Application, PHDE030227, July 25, 2003.

G. R. Hiertz, J. Habetha , P. May , E. Weiss, R. Bagul, S. Mangold: A Decentralized Reservation Scheme for IEEE 802.11 ad hoc networks. In *Proc. IEEE Personal Indoor Mobile Radio Conference (PIMRC)*, Bejing, Sep. 2003.

G. Hiertz, J. Habetha: A new MAC Protocol for a wireless multi-hop broadband system beyond IEEE 802.11. In *Wireless World Research Forum*, 9th Meeting in Zurich, Switzerland, July 2003.

Claims

1. A method of decentralized medium access control in a communications network consisting of a plurality of stations, wherein devices include reservations for planned transmissions in their beacon frames.

2. The method of claim 1, wherein a reservation is included in the beacons of the sending as well as receiving devices of the respective planned transmission.

3. The method of claim 1, wherein the beacons of all terminals are grouped into a beacon phase.

4. The method of claim 1, wherein said sending device carries out a negotiation process with said receiving device prior to a new or a change of an existing reservation, characterized by

   - Said sending device sending a Reservation-Request to said receiving device, in which the starting time, duration, priority and if necessary also channel/hopping or code sequence is included.
   - Said receiving device answering said Reservation-Request with a Reservation-Response, in which the proposed reservation is either accepted or rejected.

5. The method of claim 4, wherein said receiving device proposes an alternative starting time, duration or channel to the sending device in said Reservation-Response.

6. The method of claim 1, wherein the starting time of the reservation is given relative to the Target Beacon Transmission Time of the device, which is sending said beacon.

7. The method of claim 4, wherein the starting time of the reservation is given relative to the Target Beacon Transmission Time of the next following beacon of the device, which is sending the Reservation-Request, rsp. Reservation-Response.

8. The method of claim 5, wherein a sleep-mode operation of devices characterized by
   - a device entering sleep-mode, if it is not involved in any of the transmissions, that are announced in the beacon phase;
   - a device waking up from sleep-mode at the beginning of each beacon phase.

9. The method of claim 1, wherein devices maintain a table of all planned reservations that they have received or sent.

10. The method of claim 1, wherein a transmission consists of the following steps:
    - The receiver sending a poll packet to the sender
    - The sender sending the data packet to the receiver
    - The receiver acknowledging one or several data packets with an ACK packet.

Deep Sleep mode etc....

11. A communications network consisting of a plurality of stations, including a plurality of stations, which include reservations for planned transmissions in their beacon frames.

...